REPORT DOCUMENTATION PAGE

Form Approved OMB No. 074-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1996	Presentation, 15-20 September 1996

4. TITLE AND SUBTITLE
Status Report of the EPA's Air Pollution Prevention & Control Division's Biomass-to-Energy Development & Demonstration Projects

5. FUNDING NUMBERS
N/A

6. AUTHOR(S)
C.R. Purvis, J. Cleland, J.D. Craig, & C.F. Sanders

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

US EPA
Air Pollution Prevention & Control Div.
MD-63
Research Triangle Park, NC 27711

Cratech, Inc.
P.O. Box 70
Tahoka, TX 79373

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

SERDP
901 North Stuart St. Suite 303
Arlington, VA 22203

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
Presented at Bioenergy '96 - The Seventh National Bioenergy Conference conducted jointly with the ASAE Third Liquid Fuels Conference, Nashville, TN, 15-20 September 1996. This work was supported in part by SERDP. The United States Government has a royalty-free license throughout the world in all copyrightable material contained herein. All other rights are reserved by the copyright owner.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release: distribution is unlimited

12b. DISTRIBUTION CODE
A

13. ABSTRACT ***(Maximum 200 Words)***

The U.S. EPA's Air Pollution Prevention & Control Division (APPCD) is participating in research, development, and demonstration projects that will convert biomass energy to electrical power, resulting in waste utilization, pollution alleviation, and energy conservation. The goal of each project is to demonstrate the technical, economic, and environmental feasibility of an innovative energy conversion technology. This paper describes the status of each project.

The first project, managed by Research Triangle Institute, is a demonstration of a design by Thermal Technology, Inc. and Mech-Chem & Associates, Inc. that consists of a fixed-bed gasifier, a gas cleaning system, a spark ignited syngas engine, and a diesel dual fuel engine.

The second project is a continuation of the development of the Cratech, Inc. biomass-fueled integrated-gasifier gas turbine power plant.

14. SUBJECT TERMS
SERDP, Biomass Energy, BIGGT power plant, Syngas engine

15. NUMBER OF PAGES
6

16. PRICE CODE
N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclass.	unclass.	unclass.	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

19980709 134

Presented at: Bioenergy '96 - The Seventh National Bioenergy Conference
Conducted jointly with The ASAE Third Liquid Fuels Conference
September 15-20, 1996
Nashville, TN

STATUS REPORT OF THE EPA'S AIR POLLUTION PREVENTION AND CONTROL DIVISION'S BIOMASS-TO-ENERGY DEVELOPMENT AND DEMONSTRATION PROJECTS

Carol R. Purvis, John Cleland, Joe D. Craig, Charles F. Sanders[1]

ABSTRACT

The U.S. Environmental Protection Agency's (EPA's) Air Pollution Prevention and Control Division (APPCD) is participating in research, development, and demonstration projects that will convert biomass energy to electrical power, resulting in waste utilization, pollution alleviation, and energy conservation. The goal of each project is to demonstrate the technical, economic, and environmental feasibility of an innovative energy conversion technology. This paper describes the status of each project.

The first project, managed by Research Triangle Institute (RTI), is a demonstration of a design by Thermal Technology, Inc. (TTI) and Mech-Chem & Associates, Inc. that consists of a fixed-bed gasifier, a gas cleaning system, a spark ignited syngas engine, and a diesel dual fuel engine. The technology will use wood waste as fuel and will produce approximately 1 MWe at the Marine Corps Base Camp Lejeune, NC. The design of the technology is complete, equipment fabrication is underway, and installation, start-up, testing, and demonstration will follow by September 1996.

The second project is a continuation of the development of the Cratech, Inc. biomass-fueled integrated-gasifier gas turbine (BIGGT) power plant. Phase 1 is complete and consisted of the design, fabrication, and operation of a 0.5 metric ton per hour (tph) (0.55 tph) pressurized fluidized-bed gasifier with a slipstream hot gas cleanup system. Phase 2 is to increase the feedrate to 1 metric tph (1.1 tph) and uprate the gasifier to operate at 10 atmospheres (981 kPa) with a full scale, dry, hot gas cleanup system capable of being integrated with a 1 MWe rated gas turbine engine. Construction of Phase 2 will begin in the summer of 1996.

[1]Carol R. Purvis, U.S. Environmental Protection Agency, Air Pollution Prevention and Control Division, MD-63, Research Triangle Park, NC 27711 USA. John Cleland, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709-2194 USA. Joe D. Craig, Cratech, Inc., P.O. Box 70, Tahoka, TX 79373 USA. Charles F. Sanders, 28531 La Maravilla, Laguna Niguel, CA 92656 USA.

DTIC QUALITY INSPECTED 1

The third project is a demonstration of the ENERGEO, Inc. AGRIPOWER 200 biomass-fueled power plant at Sutton Lumber mill in Tennga, GA. The AGRIPOWER system operates with an open Brayton cycle using a fluidized-bed combustor and several heat exchangers to heat compressed air and drive a turbine/generator set. The system also discharges clean hot air which can be used for cogeneration applications. The system will use lumber wastes as fuel and will produce approximately 200 kWe. Fabrication is underway, and the demonstration is scheduled to accumulate 8000 hours of operation over a period of 1 to 2 years.

Keywords: gasification, combustion, gas turbine, engine, biomass energy

CAMP LEJEUNE ENERGY FROM WOOD (CLEW) PROJECT

Project Objective

The Camp Lejeune Energy from Wood project is intended to demonstrate a biomass-to-energy conversion technology at a scale of approximately 1 MW of electrical output, on the Marine Corps Base Camp Lejeune, NC. The 4047 m^2 (1 acre) demonstration site has easy access to all necessary utilities, is in close proximity to the Base's landfill, and is secluded from the main section of the Base. Camp Lejeune will supply wood waste for power plant operation while minimizing transport and maximizing local waste resource utilization. Over 10,900 metric tons per year (tpy) (12,000 tpy) of combined wood products and tree limbs waste are available due to activities on the Base. The waste will become the fuel for the demonstration and will be delivered in chipped or hogged fuel-size to the demonstration site.

Technology Description

A down-draft gasifier is used to produce synthetic fuel gas. The synthesis gas exits the gasifier and flows through a cyclone, heat exchangers, gas/liquid separators, and cartridge filters. The system is maintained under negative pressure by a downstream multistage centrifugal blower. The blower discharges the gas into a spark-ignited engine and diesel engine generator set. Mech-Chem designed the reactor, gas stream cleanup system, and engine generator sets, while RTI designed the fuel handling, fuel drying, and syngas sampling systems.

The fuel for the process will be dried in a deep bed dryer. The chipped wood fuel will be fed to the dryer by a walking floor trailer at a rate of approximately 1500 kg/hr (3300 lb/hr). Hot engine exhaust, from the biofuel engines, mixed with preheated air at 177°C (350°F) will be used to dry the wood, and it will be pulled through the bed at a rate of 2.45 m^3/sec (5000 SCFM). The wet fuel at approximately 40% moisture will be dried in the deep bed dryer to 10% moisture. Tests have been performed by RTI to confirm the drying rate, retention time, and pressure drop associated with the deep bed dryer. The fuel will be metered into the gasifier by the dryer as needed to maintain the proper position of the combustion zone in the gasifier.

The downdraft gasifier converts wood chip fuel into a low heating value gas [~6.7 MJ/SCM (~180 Btu/SCF)] through a pyrolysis reaction. Preheated air for combustion is provided from a heat exchanger integrated into the product gas cyclone. The preheated air that enters the reactor will only partially combust the fuel. The heat from the combustion is transferred to the wood, driving off the volatile gases by pyrolysis. The result of this pyrolysis is an activated carbon "char" bed and the low heating value gas. The char is removed from the bottom of the reactor by screw conveyor and is collected in a carbon hopper. The activated carbon is potentially a saleable by-product of the system.

A cyclone removes the particulates from the hot gas stream. The stream is then cooled to 38°C (100°F) by heat exchangers, and liquids are separated out by vertical coalescing liquid/gas separators. The impingement filters further remove tars and particulates before the gas reaches the blower. The "syngas" is pulled through the system by a multi-stage centrifugal blower. The final stage of gas cooling and cleanup includes a heat exchanger to remove blower heat -- thus reducing the gas temperature back to 38°C (100°F) -- and a liquid separator where final liquid separation takes place.

The gas is monitored and fed to two engine-generator sets (one diesel and one spark ignited) to produce 1 MW of electricity. The gas is monitored continuously for constituents including nitrogen, hydrogen, carbon monoxide, carbon dioxide, methane, and oxygen to enable overall process analysis. The efficiency and reliability of the two engines will be compared. The process is almost entirely automated. Data acquisition and analysis will cover performance, operations, economics, and environmental variables.

Schedule/Status

The cooperative agreement between EPA and RTI was signed on July 12, 1994, with a project period of 3 years. The site was selected in the fall of 1994, and the technology was selected in the winter of 1994. Agreements between RTI and TTI were signed, and final system design began in the spring of 1995. Site preparation at Camp Lejeune and equipment deliveries to the site began in early 1996. Installation should be completed in the fall of 1996. Testing and demonstration should be completed by the fall of 1997.

CRATECH'S DEVELOPMENT OF THE BIGGT POWER PLANT

Project Objective

Cratech is progressing with a plan to develop a biomass-fueled integrated-gasifier gas turbine (BIGGT) power plant capable of producing 1 MWe for commercial use. The BIGGT technology consists of a fuel feed and pressurization system, a pressurized fluid bed gasifier, and a dry hot gas cleanup assembly coupled to a gas turbine generator set.

Technology Description

The biomass is fed in a bulk biomass feed system. The feed hoppers have live bottoms capable of feeding most types of biomass. Cotton gin trash, bagasse, and wood chips are the fuels that have been used in the system during phase 1. Phase 2 will use wood chips as fuel. The biomass is fed to a size reduction hammermill if required. If moisture content is greater than 20%, drying will be a benefit; otherwise, no drying is required. The biomass is then pneumatically conveyed to the high pressure feed vessel.

The outstanding features of the biomass pressurization vessel are its small valves for the biomass inlet and outlet, and its large 2 m^3 (71 ft^3) storage volume required to minimize valve cycle times (minimum of 15 cycles per minute). These components together with the meter vessel will provide a durable system for accurately and reliably feeding all types of bulky biomass to the pressurized reactor vessel.

The pressurized fluidized bed reactor vessel was chosen because it will operate with almost any type of biomass with minimal preprocessing. There are many advantages of pressurized gasification, one of them being that the produced fuel gas can be fed to the gas turbine without further compression. The operating temperature in the reactor is approximately 750°C (1382°F).

The gas exiting the reactor is approximately 725°C (1337°F) and is thoroughly cleaned of particles that would be damaging to the turbine. The BIGGT system removes the particles under hot dry conditions using a single stage cyclone followed by a hot gas filter vessel. This cleaning process has three advantages over other types of processes: 1) no heat exchangers are needed, 2) no scrubbing is required nor is there wastewater to treat, and 3) the sensible heat of the gas is retained. The gas cleaning system was tested during phase 1 work and found to clean the gas such that the particulate concentration of the gas entering the first stage turbine rotor would be 1 ppm or less with no particle larger than 2.8 μm. This meets gas turbine cleanliness requirements.

The gas turbine inlet temperature is 700°C (1292°F). The gas turbine engine is ideal for integrating with a pressurized gasification system. It is a fairly simple heat engine that can burn the type of low heating value gas that is produced and benefits from enormous development efforts during the past few years. The gas turbine's simple cycle efficiency is gradually increasing, and its share of the cost of electricity is dropping.

Schedule/Status

The development plan is divided into three phases and is being performed at Cratech's facility in Texas. Phase 1 was the design, construction, and testing of the system with a feed rate of 0.5 metric tph (0.55 tph) at 2 atmospheres (196 kPa) pressure. The system included a slipstream flow hot gas cleanup system. Phase 2 is to uprate and test the system to a feed rate of 1 metric tph (1.1 tph) at 10 atmospheres (981 kPa) pressure. This phase will include a full flow hot gas cleanup system and integration with a 200 kWe gas turbine engine generator set. Phase 3 is to integrate the phase 2 system with a 1 MWe gas turbine engine generator set. Phase 1 of this development program is complete. Phase 2 is now underway.

ENERGEO'S DEMONSTRATION AT SUTTON LUMBER COMPANY

Project Objective

The AGRIPOWER 200 unit is to be installed and tested at Sutton Lumber Company in Tennga, GA. The unit will be operated by Sutton personnel as part of their ongoing power generation from wood wastes and is expected to produce approximately 200 kWe. The electricity generated will be utilized by the lumber mill with additional electricity supplied to the grid and sold to the TVA.

Technology Description

The AGRIPOWER 200 unit operates with an "open" Brayton cycle using a fluidized-bed combustor and several heat exchangers to heat compressed air which in turn drives a turbine/generator (T/G) set that includes a compressor and a recuperator.

There are two primary flow circuits in the process: a compressed air turbine circuit and a combustion circuit. The compressed air turbine circuit begins with the intake of ambient air by the compressor which is powered by direct connection to the turbine. The air is compressed to several atmospheres and exits through a recuperator which transfers heat from the turbine exhaust to the compressed air and improves the efficiency of the system. From the recuperator, the compressed air passes through a convective heat exchanger, recovering energy from the furnace flue gases. Then the compressed air goes to the furnace and receives additional energy via a radiant heat exchanger in the upper part of the furnace above the fluidized bed. From the radiant exchanger the compressed air returns to the turbine and expands through the turbine blades to power the compressor and the electrical generator. The turbine exhaust then passes through the recuperator and is either discharged to the atmosphere or, with a temperature of 260°C (500°F), utilized for cogeneration. Included as an integral part of the turbine is a fuel oil combustor which is used for "black" starts of the system.

The combustion circuit uses two fans to supply air to the fluidized bed and the freeboard above the bed. Both air supplies are preheated by recovering energy from the flue gases. Biomass fuel is supplied to the furnace by a feed hopper and screw conveyors. Two screws in the bottom of the hopper regulate the flow of fuel to a third screw which injects the fuel above the fluidized bed. The furnace employs both in-bed and freeboard combustion zones. The freeboard zone is well-mixed to provide uniform temperatures. The temperatures both in and above the bed are regulated to limit potential problems associated with the ash. After giving up energy to the compressed air through the radiant and convective heat exchangers, the combustion gases pass through a cyclone for removal of the fly ash. From the cyclone, the flue gases are used to preheat the combustion air streams via the air preheaters. An induced draft fan exhausts the flue gases to the atmosphere and is controlled to maintain a slight negative pressure in the furnace above the bed.

The motors for the fuel feed screw conveyors and for all fans are variable speed as part of the system control. Feedback from the power output by the electrical generator and the inlet temperature to the turbine are used to regulate the amount of fuel supplied to the furnace. Key furnace temperatures are used to control the combustion air supply. Individual controllers are utilized for each principal control loop. The individual controllers are supervised by a digital computer providing overall control of the system. If a computer fails, the individual controllers can operate independently. Under certain circumstances the computer can override the individual controllers and control the components directly. Start-up and shutdown procedures are programmed into the system computer.

The AGRIPOWER unit is equipped with a number of pressure and temperature instruments for measuring and recording operating data on a continuous basis. Through the continuous data gathering, operating and maintenance logs, and scheduled tests by the independent experts, the test program will document the operating and maintenance characteristics, determine the process performance, and define the potential environmental effects of the operating unit.

Schedule

Fabrication and shakedown testing of the unit are expected to be completed by the fall of 1996. Shipment to and installation at Sutton Lumber Company are scheduled for the fall of 1996. The test for 8000 operating hours or 2 years, whichever comes first, should begin in the winter of 1996.

ACKNOWLEDGMENTS

The CLEW Project has received funding from the U.S. Department of Defense's (DoD's) Strategic Environmental Research and Development Program (SERDP) and the State of North Carolina Department of Commerce's Energy Division with cooperation from the USMC Base Camp Lejeune, RTI, EPA's APPCD, TTI, and Mech-Chem & Associates.

The Cratech Phase 1 development work received funding from the U.S. Department of Energy's (DOE's) Western Regional Biomass Energy Program (WRBEP). Phase 2 funding is being provided by the EPA's APPCD, DoD's SERDP, and WRBEP with contract assistance from the Tennessee Valley Authority (TVA) and the State of Vermont.

The ENERGEO demonstration has received funding from the DOE's Office of Utility Technologies' Solar Thermal, Biomass Power, and Hydrogen Technologies Division and DoD's SERDP with contract assistance from the TVA and technical monitoring by the EPA's APPCD.